Are All Sciences Created Equal?

By Dag Forssell 1994

ABSTRACT:

Sciences of today are not created equal. The physical sciences we depend on today were not always dependable. The life sciences we cannot and should not depend on today may become dependable in the future. While *Perceptual Control Theory (PCT)* deals with a "fuzzy" subject, it differs from contemporary life science in the kind and quality of explanations offered. To clarify this difference, categories of experience and explanation are defined and illustrated. PCT is not explained in this paper, but perspectives, basics and some explanations are discussed.

Introduction

I have long been interested in "what makes people tick." When I read *Behavior: The Control of Perception* by William T. (Bill) Powers, the detailed, in-depth explanations made perfect sense to the engineer in me. Demonstrations were compelling in their universal application and validity. I found the book very different from seminars, books and tape programs I had studied before. Powers provides a lucid synthesis, showing how neurons interacting in a hierarchy of control systems can account for most of the phenomena we experience.

I found that applying my understanding of PCT can help me develop and maintain pleasant, productive personal relationships on and off the job. PCT shows me that I am an autonomous living control system, and I value my ability to control my perceptions freely. In my roles as father, husband, friend, teacher and manager, I now strive to support others, especially those close to me, to control their perceptions in a way that is satisfying to them. This motivates me to teach PCT.

I have become acutely aware that PCT has been distorted, misunderstood, oversimplified and dismissed by scientists who deal with the descriptions and explanations PCT improves upon—or replaces. I have wondered why some people grasp and appreciate PCT with ease while others find it difficult to understand, accept or both. There appear to be two reasons for this.

The first reason, well explained by PCT, is that once a person has been taught an idea and decided to believe in it, that idea becomes part of the person's control hierarchy and any suggestion that the idea is false is resisted. Kuhn (1970), shows how this has been true for many scientific revolutions. Any adult has woven a personal web of ideas of how people "work." Suggestions that don't fit this web of principles and systems concepts are quite naturally resisted—or misinterpreted or distorted so they do fit.

A second reason may be that there are significant differences between the kind of theory and explanation scientists are used to in different fields, and that these differences make comprehension difficult. Scientists who are used to deal with descriptions alone may fail to understand the kind of explanation PCT offers. In this paper I address this second reason by discussing theories and explanations. "Theory" can mean anything from a hunch to a law of nature. I propose the categories *Experience, Description, Descriptive Non-Explanation*, and *Causal Mechanism,* and shall point out the advantages of causal mechanisms.

Language and expectations

We like to say that we live in a scientific age. Every day newspapers and TV programs announce new findings by scientific researchers. Scientific research done by a scientific method suggests definitive information, double-checked by researchers and 100% valid. This interpretation may be overly generous. All sciences are *not* created equal. Some very important fields of science are not very scientific at all, lacking explanations that have proven valid.

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Theory and science go together, but in popular usage the word *theory* can mean anything from a casual hunch based on personal experience (which is hard to articulate) to a law of nature which has been confirmed in innumerable rigorous experiments. A *paradigm* means any personal way of looking at the world. A *science* means a field of study. A *scientist* means anyone doing *research,* no matter how. The new theories and scientific research we hear about on the evening news vary all the way from conjecture and questionable statistical "facts" to newly discovered, experimentally confirmed laws of nature.

Bill Powers writes about different interpretations of theory on an E-mail network:

> Theory, as I see it, purports to be about what we can't experience but can only imagine [with respect to PCT:] (neural signals, functions like input, comparison, output and mathematical properties of closed feedback loops), while evidence is about what we can experience. Both theory and evidence are perceptions, but the way we use these perceptions in relation to each other puts them in different roles.
>
> In the behavioral/social sciences, the word "theory" seems to mean something else: a theory is a proposition to the effect that if we look carefully, we will be able to experience something. A social scientist can say "I have a theory that people over 40 tend to suffer anxiety about their careers more than people under 20 do." The theory itself describes a potentially observable phenomenon. The test is conducted by using measures of anxiety and applying them to populations of the appropriate ages. If we observe that indeed the older population measures higher on the anxiety scale than the younger, we say that the theory is supported—or, as some would put it, the hypothesis can now be granted the status of a theory that is consistent with observation.
>
> This meaning of theory leads to the popular statement that a theory is simply a concise summary of, or generalization from, observations. That definition has been offered by quite a few scientists past and present. I think it misses an essential aspect of science, the creative part that proposes unseen worlds underlying experience. Before the "unseen worlds" definition can make any sense, however, it is necessary to understand, or be willing to admit, that there is more to reality than we can experience. . .

Scientific perspectives

A traditional scientific perspective. It is my impression that most adults take the world for granted. I do. As adults discussing the world, we all have a sense of what some call *objective reality*. We see it in living color, touch it, hear it, smell it, chew it, walk on it, and swim in it. Sometimes we hit it, or it hits us, and it hurts.

Most of us agree that some mental constructs have no equivalent in the physical world we live in. They are what we call *subjective* or *personal*. There is no way to definitively compare one person's subjective impression of things like beauty, marriage, courage, friendship, loyalty, ownership or self-esteem with that of another. What is unclear is where to draw the line between the objective and the subjective.

In electronics, engineers sometimes talk about *black boxes*—electronic assemblies or mechanisms with secret insides but observable and most often very dependable functions. One could say that the function of science is to uncover the secrets of the black boxes we find in nature. In management or behavioral science, the black box is the human being.

An alternative scientific perspective. Instead of taking the world for granted and studying the brain as a black box, we can take the brain for granted and look at the world outside the nervous system as the black box. The challenge now is making sense of that world, starting from the time of emerging awareness in the nervous system of a fetus still in the womb. To see how the nervous system can possibly make sense of its environment, we will need to consider the best available information about neurology, mechanics, physics, chemistry, and biology. We may learn more about the brain looking out from the inside than in from the outside.

Some observations about nerves. Nerves interact with our physiology and the world around us to create the high level human experience we take for granted. Researchers in the fields of biology and neurology tell us that:

1) Nerves are capable of sending streams of pulses through their fibers. Frequencies range from zero to about 1,000 pulses per second. Propagation velocity ranges from 50 to 300 meters per second, which approaches the speed of sound in air.
2) The rate at which pulses are sent appears to be caused by a variety of influences, singly or in combination. Pulses may be originated by

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the neuron itself (some continue throughout life), or result from light, vibration, chemicals (hormones), pressure, stretch, temperature, and electricity. Pulses from connecting nerves are another typical source, causing pulses to propagate from nerve cell to nerve cell. A stream of pulses can be called a neural current. Depending on how the neurons are arranged and connected, currents can be added, subtracted, branched, multiplied, integrated, etc., making almost any logical manipulation possible.

We can never know REALITY. Philosophers have argued about what really exists. I accept that the physical world exists, and that we as physical entities are part of and exist in this physical world. The physical world as it exists, I call physical REALITY. I recognize that we are limited in what we can know about the REALITY we are part of. I call the representation we develop in our minds perceptual *reality*.

The complexities of nerves and nerve function are interesting in their own right and will be the subject of detailed research for centuries to come. The intent here is simply to note that all the nervous system can possibly know about its environment (REALITY) are the neural currents travelling in nerve fibers *(reality)*. No organism can possibly have direct knowledge of the world around the brain (REALITY), even though it sure looks that way and many scientists who have not considered this, take for granted that we do. Exhibit 21.

With this realization, it is no longer useful to draw a line between the objective and the subjective. All anyone can know is subjective *reality*. But the dependability—the effectiveness—of a person's personal *reality* varies greatly. Most of us experience it as 100% dependable when dealing with simple physical phenomena. At the same time, we experience it as uncertain when we deal with high-level mental constructs, both in ourselves and in other living beings. Good theory serves to improve the quality of this uncertain *reality* so that we can deal more confidently with the REAL world we live in.

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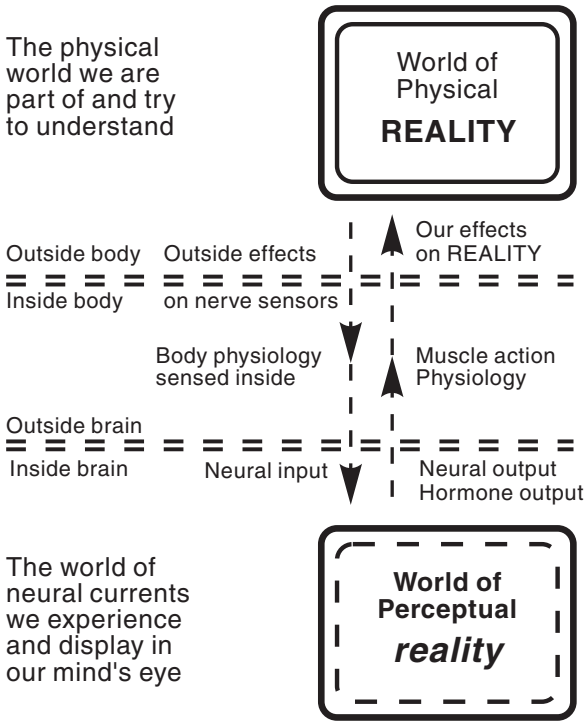

Exhibit 21. REALITY outside. *reality* inside.

Infant perspective: The world as a black box. The challenge for the developing infant is making sense of the currents in its nervous system as signals representing the world outside the brain. The currents originate in a variety of nerve-cell sensors inside the body: in organs and muscles, in eyes and ears, in the nose, mouth and in the skin.

Adult perspective: The brain as a black box. A challenge for life science is to determine the organization of our nerve cells. Taken together, nerve cells make sense of all these currents and develop into a human brain. The adult experiences the world in living color with stereophonic sound—then turns around, takes the world the infant brain has made sense of for granted, ***as if*** it is experienced directly, and asks questions about the mysterious brain.

Making sense of the black boxes. I certainly don't remember when I became aware of my existence. Adults don't remember much of their early development, but as adults we can observe that the development of infants is rapid. Fetuses still in the womb move about, kick, probably listen and may suck their thumb. A newborn is clumsy at first, but by trial and error finds out what works. When nerves sensing hunger, thirst, heat or cold send signals, other

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signals are created in the brain, perhaps at random in the beginning, causing the little body to act. If a particular act alleviates the problem, the signals that caused it become part of the brain's specifications to keep itself satisfied; to minimize those hunger, thirst, heat or cold signals. For example, many babies try crying and discover that—as if by magic—crying helps eliminate problems.

As the infant and its brain develop, the brain receives perceptual signals from organs deep inside the body as well as at the surface and sends out neural and chemical signals, causing the muscles to contract, organs to change, and the body to act on the world. The brain senses the new condition. Over time it develops a structure and memories that allow it to effectively act on the world so that the perceptions it experiences are the ones it wants to experience. *The brain acts* (sends neural and chemical signals to muscles and organs) *in order to affect what it experiences*. As time progresses, the baby learns to control its perceptions in ever more sophisticated ways.

As the baby focuses its eyes, coordinates its limbs, enjoys stroking, recognizes sounds and tastes everything it can bring into its mouth, the brain develops a *reality*, an interpretation of the world around the brain. We might say that the baby does scientific research and develops paradigms about the world. In this sense there is no difference between Nobel Prize science and an infant exploring its world. We are all scientists from the beginning of our awareness. But just as Eskimos have many words for different shades of white, we need several words for different shades of theory.

Tools for explanation

Before I discuss theory and explanation, I will review tools we use to describe and explain.

Language: Categorization and generalization. As humans, we benefit from a well developed capability to hear and utter sounds. The infant soon learns to associate sounds with experiences. While some sounds are associated with singular experiences, many words soon come to represent a whole class of experience. The meaning of food, chair, tired, hurt, shoe, walk, sit, and high include several possible configurations of objects, feelings, posture and physical relationships. Language facilitates generalization. Instead of having to duplicate experience, we can describe and categorize experiences.

Logic and Reasoning. Logical reasoning, mathematics and geometry are in a class by themselves. Based on idealized hypothetical postulates, they are logically rigorous. They do not represent physical experience. Therefore, they are not physical sciences, but are valuable as supplements to our descriptive language—tools to manipulate and give precise meaning to descriptions and mechanisms of all kinds, at all levels of sophistication, in all the physical sciences.

Measurement. Measurement is a different kind of tool, linking physical experience with description. Careful measurement has been very important to the development of modern physical science, as exemplified by Galileo's measurements of acceleration.

Statistical Analysis. A special branch of mathematics, statistics is widely used as a diagnostic tool. High correlations between observed variables can prompt guesses about underlying causal mechanisms, which can then be tested to see if the guess is valid. But it is important to recognize the strength as well as the limitation of statistics. In his book *Scientific Explanation and the Causal Structure of the World*, Wesley Salmon (1984) writes:

> Even if a person were perfectly content with an "explanation" of the occurrence of storms in terms of falling barometric readings, we should still say that the behavior of the barometer fails objectively to explain such facts. We must, instead, appeal to meteorological conditions. ... Statistical analyses have important uses, but they fall short of providing genuine scientific understanding .... A rapidly falling barometric reading is a sign of an imminent storm, and it is *highly correlated* with the onset of storms, but it certainly does not *explain* the occurrence of a storm.

Statistical descriptions are useful in terms of populations, whether of people or products, and can be used for prediction in terms of populations. But making decisions about individuals based on statistical prediction amounts to abuse. We call it prejudice. For a discussion of strengths, limitations (why statistical methods are incapable of delivering the secrets of human nature) and misapplication of statistics, please read *Casting Nets and Testing Specimens: Two Grand Methods of Psychology* (Runkel, 1990, 2007).

The time has come... to put the "cause" back into "because."

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Theory, explanation and prediction

Experience. PCT shows that organisms control perceptions, not actions. This explains why organisms do not need to "understand" their environment and why faulty explanations discussed among humans are simply ignored in practice. All an organism needs to do is to pay attention to a perception it wants to control while it acts and remember which way actions influence the variable. An infant lying in the crib reaches for an object hanging overhead. At first the image may be fuzzy and the hand miss the object, but the infant does not give up. It persists and over weeks, months and years learns by trial and error to act on its world so that it can experience it the way it wants to. As adults we have accumulated a large "world" of perceptions which make up and help us function in our individual *perceptual reality*. We call it *experience*. Predators teach their young to hunt through play, demonstration and practice. Consider the tradition in many arts of the master showing the apprentice what and how to perceive: what to look for, how it should feel, sound, smell and taste. We describe only a fraction of our perceptual reality in words. Exhibit 21 and 22.

Predicting from experience. The word hunch captures the idea of theory and prediction in the nonverbal world of *experience* at a very simple level. When we express a hunch we use a few words to summarize a vague or complex notion that we sense, visualize or imagine in the world of perceptual reality, but cannot put into words.

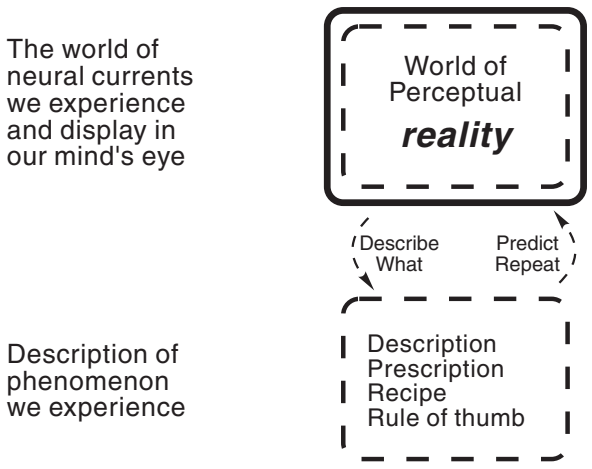

Exhibit 22. Experience and description

Verification and dependability of experience. The words hunch, gut feel, wisdom, and mastery suggest degrees of confidence in the predictions we make from experience.

Description. Language allows us to describe our experiences. It becomes possible to learn from experiences of others without having to take the time or suffer the risk of duplicating the experience itself. Our infant becomes a toddler and begins to express experiences in words. Lemons taste sour. Fire burns your skin. Objects fall when you release them. These are simple *descriptions* of phenomena we experience. Exhibit 22.

Prediction from Description. I can now predict that if I bite into another lemon, I will experience sour taste. If I touch fire, I get burned. I predict that when I release an object, it will fall. Predictions are based on regularities; things that usually happen "other things being equal." We use *Rules of thumb*, *Prescriptions* and *Recipes*. Exhibit 22.

Verification and dependability of descriptions. Since descriptions can be shared, they can be compared and the rules can be tried by many people, under different circumstances. We find some rules to be very dependable, while others are uncertain.

Descriptive Non-Explanation. Our preschooler pesters mother with questions. Why, Mother? Why is the Dandelion yellow? Why doesn't the rope break? Because! Because it is strong. Our little scientist is asking questions to make sense of the black box that still holds secrets everywhere you look. Some of mother's answers fit the category of theory I call *Descriptive non-explanation:* The Dandelion is yellow because all Dandelions are yellow. The rope does not break because it is strong, but strong is defined by "does not break." We notice that these are not explanations at all, but restatements or further descriptions of the same experience.

We often explain a phenomenon by using its description, somewhat transformed, as its explanation: You have trouble reading because you are dyslexic. By switching from the English "read" to the Greek "lexia" you make it sound as though you are naming a cause, whereas in fact you are simply repeating the description in a sentence that has the form of an explanation. In one of Molière's plays, a physician explained to a patient that sleeping medication worked because it contained "dormitive principles," where dormir is French for sleep. This term has

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been used to signify descriptive non-explanation. This is a popular mode of explanation in any field where people keep pestering you for explanations and you find it embarrassing or impolitic to keep saying "I don't know." Exhibit 23.

Exhibit 22 continued:

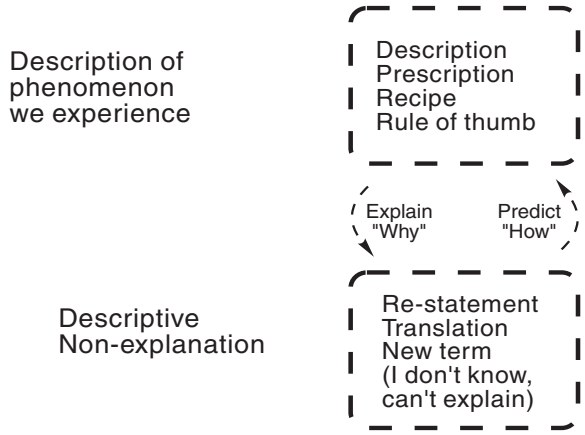

Exhibit 23. Descriptive Non-explanation

There really isn't any difference between descriptions and descriptive non-explanations except for the pretense of explanation and the introduction of a new term. The new term is incorporated in our language.

Causal mechanism. Wesley Salmon (1984) advocates causal mechanisms:

> The time has come, it seems to me, to put the "cause" back into "because." ...The relationships that exist in the world and provide the basis for scientific explanations are causal relations. ...To understand the world and what goes on in it, we must expose its inner workings. To the extent that causal mechanisms operate, they explain how the world works. ...A detailed knowledge of the mechanisms may not be required for successful prediction; it is indispensable to the attainment of genuine scientific understanding.... Explanatory knowledge involves something over and above merely descriptive and/or predictive knowledge, namely, knowledge of underlying mechanisms. ...To untutored common sense, and to many scientists uncorrupted by philosophical training, it is evident that causality plays a central role in scientific explanation. An appropriate answer to an explanation-seeking why-question normally begins with the word "because," and the causal involvements of the answer are usually not hard to find.

Causal mechanisms suggest the property, structure or functional relationships and interactions of elements below the level of described phenomena. Initially made up in one person's creative imagination, causal mechanisms offer explanations of why and how things happen. The physical sciences, based on causal mechanisms, have progressed far. Exhibit 24 illustrates a series of causal explanations in principle, reaching deep below the surface of the experienced phenomenon and its description.

> A detailed knowledge of the mechanisms may not be required for successful prediction; it is indispensable to the attainment of genuine scientific understanding

Prediction from causal mechanisms. Visualizing the operation of the mechanism in different circumstances, we can predict what effects will emerge. We gain a deeper understanding of what is meant in any given instance when we make a prediction based on some regularity; things that (with high confidence this time) happen "other things being equal." What must be equal? In what way must it be equal? (Ways that allow the mechanism to operate). What does not have to be equal? (Things that do not affect the mechanism). Even a single level of causal mechanism below the level of the phenomenon allows much better prediction.

Verification and dependability of causal mechanisms. We can predict how the mechanism will perform in a multitude of circumstances, even ones we have never experienced before. Experimentation allows us to either reject the proposed mechanism as false and therefore unable to improve our predictions of what will happen, or as 100% dependable. With several levels of such dependable causal mechanisms in the physical sciences, one explaining the other, we have been able to travel to the moon and beyond.

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Applications of theory

Causal mechanisms, descriptions and personal non-verbal experience mix when applied. Physical science, rich in causal mechanisms, depends on descriptive empirical data at several levels. A largely descriptive science may have pockets of insight that are of a causal mechanistic nature, whether formalized or not.

To illustrate, I'll share my perspective on applied sciences:

Medicine. Much of medicine is unexplained, and descriptions of symptoms (syndromes) abounds. Much drug research is done by systematic trial and error, just like Edison developed the light bulb. Practicing physicians know that a large part of their job is to comfort and support their patient while nature takes care of healing. Descriptive non-explanations are popular: you have red itchy eyes because of conjunctivitis[1], a red itchy nose because of rhinitis[2], and are cross-eyed because of strabismus[3].

Medicine has made great strides in the last century thanks to the discovery of some causal mechanisms explaining what happens in the body. One example is the discovery of the mechanism of bacterial growth causing the phenomenon of infection. People have learned to avoid harmful bacterial growth through hygiene. Scientists have learned to interfere with bacteria through vaccination and antibiotics, reducing infectious disease. We know that you get other diseases through the mechanisms of virus growth, but have had limited success in interfering with these mechanisms.

When repairing mechanisms of the body, surgeons successfully employ many different causal mechanism explanations derived from the physical sciences.

Mechanical Engineering. Ancient feats of engineering are still admired today: sophisticated compound bows and arrows, ocean crossing canoes, aqueducts, large bridges.

We have few records of exactly how these things were designed and built, but I think it is fair to say that they were based on experience and description, along with some causal mechanism explanations.

1 **c̲on·j̲uñc·tī′và,** n, the mucus membrane lining the inner surface of the eyelids, covering the front of the eyeball.

2 **rhï•nï′tis,** n. [*rhino-* and *-itis.*] inflammation of the mucous membrane of the nose.

3 **strä•bis′mus,** n. [from Gr. strabismos; *strabizein,* to squint; *strabos,* twisted.] a disorder of the eyes, as cross-eye, in which both eyes cannot be focused on the same point at the same time; squint.

Exhibit 21 and 22 continued:

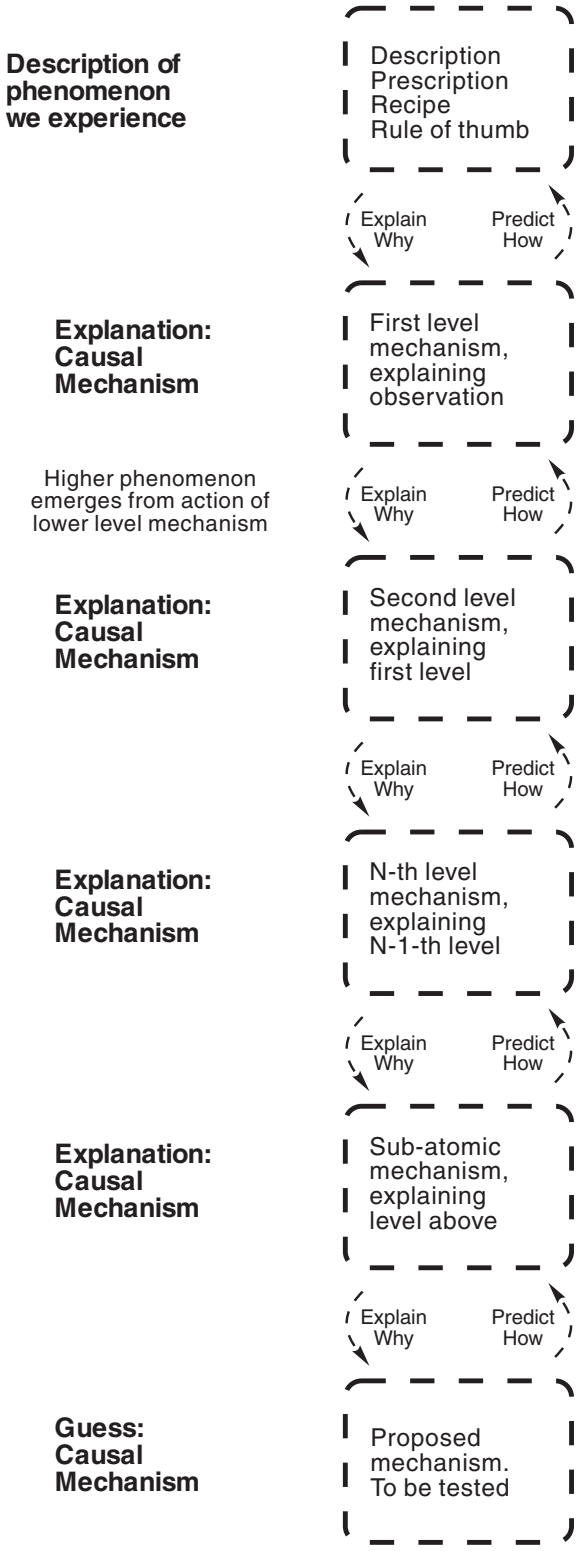

Exhibit 24. Causal mechanisms in depth.

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With the advent of the Newtonian laws of nature in the late 1600's and the new rigor of measurement and test of theoretical models, the physical sciences began a development that is qualitatively different from what went before. The new causal mechanisms are much more consistent with observation and provide explanations in much greater depth than had been possible. The last few centuries have seen unprecedented progress in engineering. Causal mechanism explanations, coupled with descriptive data (about such things as material properties) have allowed us to extrapolate from small experiments and design complex machines. But we still have no idea what is causing gravity; we can only measure it and speculate about possible causal mechanisms to account for it.

Railroads, the Golden Gate bridge, aircraft, spacecraft, television, computers... The list of modern engineering accomplishments is long. They depend on the development and verification of in-depth causal mechanisms.

Chemistry. I am aware of three phases of chemistry. To describe the first, let me quote from *Alchemy: Ancient and Modern*, by H. Stanley Redgrove (1911):

> ... we find a school of Arabic alchemy arising in the eighth century A.D. Its inspiration was primarily Hellenistic, and from the contents of many of the texts, much of its theory and practice derived from Egypt. ... The basic idea permeating all the alchemistic theories appears to have been this: All the metals (and, indeed, all forms of matter) are one in origin, and are produced by an evolutionary process. The Soul of them all is one and the same; it is only the Soul that is permanent; the body or outward form, i.e., the mode of manifestation of the Soul, is transitory, and one form may be transmuted into another. ...The old alchemists reached the above conclusion by a theoretical method, and attempted to demonstrate the validity of their theory by means of experiment; in which, it appears, they failed. ...The alchemists cast their theories in a mould entirely fantastic, even ridiculous—they drew unwarrantable analogies—and hence their views cannot be accepted in these days of modern science.

Alchemy in its long history produced products of many kinds—metals, plating, medicine. Alchemy was a descriptive science, a body of prescriptions and recipes based on accumulated experience. The causal mechanism explanations it suggested were failures.

The next phase was dominated by *Phlogiston Theory*. This was an explanation for combustion proposed by Johann Becher (1635-82). It postulated that combustible materials contained an odorless, colorless, weightless (it would rise when released) material called *Phlogiston*. The search for Phlogiston gave direction to much experimentation and by 1775 resulted in the isolation of what was thought to be dephlogisticated air. Today we call it *Oxygen*.

Thus the causal mechanism of Phlogiston failed but was replaced by new explanations for combustion, which we are confident of today. Since the discovery of Oxygen, the science of chemistry has made rapid progress, and is now supported by many additional in-depth mechanisms such as the periodic table of the elements, atomic structure and chemical bonds.

Astronomy. To say that the Sun travels across the heavens in a chariot is indeed to propose a causal mechanism. This and other explanations of celestial phenomena were supplanted by Ptolemy's *Earth centered* model of the universe (c:a AD 140), which placed the Earth at the center of the universe with the heavenly bodies in circular orbits around it. It was apparent that some bodies traveled in reverse periodically, so epicycles, small circular motions, were superimposed on the major circular motion, to describe the apparent paths of individual planets. Over time, this model grew increasingly complex.

Copernicus published an alternate, *Sun centered*, causal mechanism in 1543. This model actually provided predictions which fit observations worse than the existing model. Galileo (1564-1642) developed and published much physical evidence in support of this model. Johannes Kepler (1571-1630) inherited Tycho Brahe's (1546-1601) twenty years of meticulous, descriptive astronomical records, spent additional decades analyzing them, concluding that the planets moved in *ellipses*, not circles. The fit between prediction and data improved. The fit became perfect when Isaac Newton (1642-1727) placed the sun not in the center of the ellipses, as Kepler had done, but in one of two ellipse *focal points*. Newton suggested causal mechanisms to explain how the elliptical motion is created by the heavenly bodies in motion, tugging on each other with (the still unexplained phenomenon of) gravity.

This sequence is interesting as it moves us from an elaborate causal mechanism that appears to work but is fundamentally mistaken, to a fundamentally sound

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mechanism that appears to work worse, through refinements in several stages to a 100% dependable causal mechanism that today gives us precise results as we continue to map the universe and send spacecraft to the far ends of our solar system.

Psychology: Professional insecurity. Several psychological theories compete for acceptance, with many methods competing for practical use. Many psychologists say that their psychological theories and clinical practice have nothing to do with each other. Scientific psychologists and clinical psychologists have separate societies and professional journals. The diversity of opinion in this field is bewildering. To an electrical, mechanical, or chemical engineer, it would seem strange indeed to be told that there are several electrical, mechanical, or chemical theories, and that practical applications have little or nothing to do with any of the theories.

Psychology: Experience. We all develop an understanding or "feel" for how to deal with people. Most of this "feel" is very personal, intuitive and difficult to express. The style, personality and interpersonal effectiveness that develops from personal experience vary considerably.

Psychology: Description. The vast majority of research in psychology describes apparent phenomena and attempts to relate one description to another by statistical correlation, implying some underlying causal relationship. Such relationships (tendencies, propensities) often are reported despite correlations which sometimes approach pure chance. Over time, stripped of the original uncertainty, many such relationships attain the status of "fact," referred to by subsequent researchers and widely discussed in media. Hidden by statistical summaries are large numbers of counter-examples, where observations are the opposite of reported and popularized "facts." Given more stringent criteria for facts of the physical sciences, where a single counter-example disproves theory, a large number of accepted facts in psychology must be recognized as groundless and simply false. It is unfortunate that psychological descriptive theory is not discarded in the face of counter-examples which disprove it. Instead, uncertain tendencies are used for prediction and judgement of individual behavior. This does not help us resolve conflicts, develop personal relationships, educate capable parents or managers and understand the dynamics of leadership.

Psychology: Descriptive non-explanation. Many popular explanations in this field are descriptive non-explanations. To illustrate, let us take a look at emotion. William T. (Bill) Powers, the creator of PCT, wrote on an E-mail network:

> Emotions are hard to untangle because some people place great value on emotions and don't like to think that emotions might have a rather simple explanation. Emotions, traditionally, are treated as a separate branch of motivation, reaction, or experience, having a somewhat mysterious kind of existence that is neither physical nor mental. Scientists decry arguments that appeal to emotion rather than reason. Their opponents often sneer at emotionless scientists for their coldness or indifference to feelings. Both, when asked to explain what they mean, fall back on descriptive non-explanations.
>
> Consider the emotion called anger. How do you know when you're feeling anger? In one episode of the television series *Star Trek: The Next Generation*, the android Commander Data asks this question of Geordi, the blind Chief Engineering Officer. In an effort to learn, Data asked Geordi to describe anger without using the word "angry." Geordi (and presumably, the show's writers) are at a loss. "You just—you know—feel *angry*." If you don't know what anger is, how can you understand a description of it? Geordi refuses to fall back on a descriptive non-explanation, and admits that he can't describe anger.
>
> Well, what does happen when you feel angry? You feel a surge of sensations from your body, and an urge to do something energetic to something. If you have no "self-control" you may well lash out and do damage to something or somebody—anger most often has an object at which you're angry, and it's usually a person.
>
> The term anger refers to an experience of a surge of bodily feeling and an urge to do something extreme. Anger is just the short way of saying "bodily feeling and an urge to do something." "Anger" isn't an explanation: it's a word referring to a phenomenon that needs an explanation. You don't feel the sensations and the urge to act because of anger, or vice versa. You feel the sensations and the urge to act, or alternatively, you feel anger. The two ways of putting it say the same thing. The word "anger" and the phrase "a surge of bodily feeling and an urge to so something extreme" refer to the same experience. What passes for an explanation is actually a descriptive non-explanation.

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Psychology: Failing causal mechanisms. Two major suggested causal mechanism dominate psychology today: behaviorism and cognitive psychology.

Behaviorism[2] suggests that organisms respond to stimuli: What people do depends on what happens to them. Behaviorism includes the ideas of operant conditioning, reinforcement, and affordances; properties of the environment that somehow stimulate us to do what we do. Behaviorism has had a major influence on the psychological understanding of today's teachers and managers. It lays the scientific foundation for our society's love affair with reward and punishment. Data from experiments has varied, so additional, unexplained and unidentified internal and external stimuli have been proposed to account for any mismatch. Critics point out that "behavior" and "stimuli" both are poorly defined.

A major problem with the causal mechanisms suggested by behaviorism is that organisms not only experience stimuli, they create their own. Their behavior obviously, immediately and continuously changes the stimuli that supposedly cause the behavior.

Cognitive psychology describes many phenomena of perception and suggests that behavior is the execution of plans created in our minds.

A major problem with the causal mechanisms suggested by cognitive psychology is that when the brain has to calculate the signals sent to muscle fibers, things will start to go wrong the moment the world around the organism changes. The world may not change in the laboratory, but it sure does in everyday life.

Another problem for contemporary psychological research can only be understood once basic PCT has been understood. The scientific method used in both physical science and psychology simply put is this: Push here and see what happens there. (Change the Independent Variable and observe the Dependent Variable). This method shows what happens naturally with inanimate physical objects, but *not* with animated, active control systems. Control systems resist disturbances! You can learn from the presence or absence of this resistance, but you must understand how a control system works and that you are in fact dealing with a control system. PCT shows that the scientific method has been used incorrectly in psychological research and that all such research must be questioned.

2 **bē·hav′iŏr·izm,** n, in psychology, the theory that all investigation of behavior must be objective or observed as [because] introspection is considered invalid.

Psychology: Present status. Great variation of psychological terminology and interpretation has made it very difficult to agree on consistent descriptions of results. Psychological research is often published despite poor correlations. Studies are rarely replicated to confirm results through independent experimentation, as is routinely done in basic research in the physical sciences. I was startled the first time I was told by a psychologist that psychological theory and practice have nothing to do with each other. Now I understand that this schism is necessary for wise practice based on accumulated experience, since the causal mechanisms offered have not proven valid. But I don't accept that this state of affairs is the nature of science, which the psychologist also claimed.

> Scientists must first understand the new explanation before they can see what is wrong with the old one.

Psychology of the future: Successful causal mechanism.
Organisms live and behave in a world full of influences (disturbances), some of them invisible, (crosswind when you drive), which affect our world (direction of the car) just like our actions (steering) do. These influences should produce instability and failure since they affect outcomes of our actions, but do not. The reason is that our actions automatically compensate for invisible disturbances. The causal mechanisms of psychology discussed above fail because they do not recognize and cannot deal with disturbances in a changing world.

We overcome disturbances and achieve consistent ends by variable means in a changing world because we control. PCT offers a clear and compelling explanation for the phenomenon of control.

HPCT suggests an architecture—an organization in principle of the entire nervous system—suggesting how a system of control systems made up of neurons can develop in the infant and make sense of the world, the black box outside the system.

Neurologists have identified the structure and organization of the neurons surrounding muscle fibers as a control system called the *tendon reflex loop*. A tendon receptor senses tension and sends a perceptual signal (current) representing the tension. A *reference signal*, a signal specifying the momentarily desired

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tension, arrives through a string of neurons from a higher level in the nervous system. The last neuron in this chain is called the *spinal motor neuron*. The current conveyed through this cell stimulates the muscle fiber to contract, increasing tension at the tendon. A branch of the perceptual signal from the tendon receptor contacts the spinal motor neuron and inhibits its pulse rate. The result of this arrangement is a *comparison* (subtraction) of the stimulating current specifying tension and the inhibiting current reporting perceived tension. This difference is called an *error signal*. In this diagram, the error signal drives muscle contraction directly. In the PCT architecture, a high-level error signal works through other control systems and neural *output functions* to drive *action*. Exhibit 25.

This causal mechanism of neuron interaction explains the lowest level of muscle control we observe when we use muscles in our own bodies and when we experiment on the muscles and nerves of simple animals.

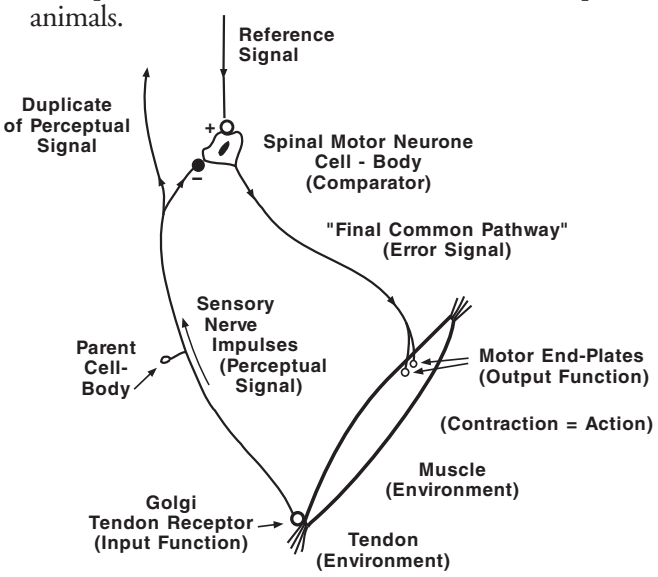

Exhibit 25. The basic first-order control system; the tendon reflex loop. (Powers, 1973).

PCT explains feelings. Bill Powers continues his discussion of emotion:

> How would we explain the experience of anger in terms of the PCT control architecture? Clearly, "a surge of bodily feeling" is a perception, and an "urge to do something extreme" implies a control system containing a large error signal. Why, we may ask, would the occurrence of a large error signal in a neural control system be accompanied by a surge of bodily feeling? One answer that seems reasonable is that the same output of the control system in question that would set reference levels calling for extreme action by the lower motor systems would also set reference levels calling for an altered state of the biochemical systems that support action. Thus we would expect blood sugar to rise, respiration to increase, heart-rate to increase, and so forth—the so-called "general adaptation syndrome." These sudden changes in somatic state can obviously be sensed; they are experienced as bodily feelings.
>
> So when a reference signal is suddenly changed to a relatively extreme value, or a large disturbance suddenly appears, the result is an error-signal-driven urge to change the state of the motor systems and the state of the biochemical systems by a large amount. There is thus a surge of sensation from the body as the biochemical systems are called upon to change to a significantly different state.
>
> Under normal circumstances and in a well-balanced system, the heightened state of preparation of the body is immediately "used up" by the accompanying motor action. There is a momentary sense of elevated somatic state that is simply part of the sensed action. The word "anger" would not be likely to be used to refer to the result.
>
> If, however, the person who experiences the large error has good "self-control," a conflict immediately ensues. One control system receives a reference signal implying an immediate change of state of the whole system, and at the same time a second control system says "No, a civilized person like me does not punch a boor in the nose, whatever the provocation." The "civilized" system cancels the reference signals going to the motor systems, and the punch does not take place.
>
> However, the control system gearing up for the punch is still there, and it is still telling the somatic systems to prepare for violent action. This state of preparedness is now not dissipated by the appropriate motor behavior and disappearance of the error signal; it is maintained by the same error signal that would throw the punch if lower systems were not receiving canceling reference signals from the "civilized" system. The reference signal calling for extreme action is not matched by the appropriate perception, so the urge to act continues and the sensation from the body persists, too. **Now** the person would say "I am angry!"

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Moreover, the person would say "I am angry **at him**." The person still wants to see and feel a fist mashing the other's nose, the other person crying out in pain, falling, becoming abject and apologetic and tearful and otherwise suffering all the embellishments of a thoroughly satisfying retribution. All these desires are the immediate source of the reference signal that suddenly changed so as to call for an energetic punch. As long as these desires are in effect, the "civilized" system will have to keep canceling the actual motor reference signals, and the anger and hatred and whatever else we call it will continue. The emotion will persist until the source of the reference signal is turned off. One ceases to be angry when one ceases to want retribution.

This is a PCT explanation of anger that does not rely on a descriptive non-explanation. The same can be done for all the other experiences we label with emotion-names. The feeling component is the perception of a change in the biochemical state of the body, or more generally, somatic state. The goal-component is the reference signal that is calling for both motor action and the somatic state appropriate to the action. If the goal is to get the hell out of there, the same somatic changes take place as in anger, but now the combination of goal and feeling is called alarm, fear, fright, terror, panic, and so on. When the action is prevented from succeeding in achieving the goal, the emotion is felt the most strongly.

Powers concludes:

> True connoisseurs of emotion have as large a vocabulary for describing emotions as epicures have for describing tastes and smells. We can speak of feeling annoyed, offended, irritated, provoked, exasperated, angered, incensed, aroused, inflamed, infuriated, and enraged. I've just arranged the terms under "anger" from Roget's Thesaurus in order of increasing error signal and increasing shift in somatic state, as I understand them.
>
> Notice how those adjectives imply the passive voice. It isn't common to attribute emotions to one's own desires. Emotions—particularly the somatic feeling part—seem to arise as though they're being done to us by something else. "You make me angry!" We don't understand where they come from; that's why we need causal mechanisms. In this case, the PCT mechanism tells us we gambled on the wrong voice: we produce our own emotions, which arise from what we want. All these terms should be used in the active voice, which sounds really strange when you do it: "I'm angering at you!"

PCT offers detailed causal mechanisms, subject to refinement in coming decades and centuries. It is possible to generate predictions and effective practices from an in-depth understanding of these causal mechanisms.

Productive and satisfying relationships in the work place, non-manipulative buying and selling in business, loving family relationships, effective education, confident individuals, effective counseling, better understanding of biology, neurology and medicine. The list of improvements will be long. Just like the progress we have already enjoyed in the physical sciences, they will depend heavily on the development and verification of causal mechanisms.

Obstacles to new ideas. Scientific revolutions are not easy. Kuhn (1970) writes:

> Because it demands large-scale paradigm destruction and major shifts in the problems and techniques of normal science, the emergence of new theories is generally preceded by a period of pronounced professional insecurity. As one might expect, that insecurity is generated by the persistent failure of the puzzles of normal science to come out as they should. Failure of existing rules is the prelude to a search for new ones. .... Though [scientists] may begin to lose faith and then to consider alternatives, they do not renounce the paradigm that has led them into crisis. ....The decision to reject one paradigm is always simultaneously the decision to accept another, and the judgment leading to that decision involves the comparison of both paradigms with nature and with each other.

The comparison with nature that Kuhn writes about requires the kind of scientific rigor and understanding of causal mechanisms found mostly among those schooled in the physical sciences. Professional insecurity has been present for a long time in the social sciences. A new paradigm is available: The PCT revolution has begun.

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PCT: Foundation for physical life science

Exhibit 26 illustrates layers of in-depth explanation in the format of exhibit 24.

At the level of description, PCT deals with familiar phenomena. This can create a problem when communicating about PCT, since some people (not used to causal explanations) look no further and conclude that PCT offers "nothing new."

At the first level of interaction, many lay people have a feel for how individual control (self-direction, freedom) manifests itself in autonomy, conflict and cooperation.

At the second level of explanation, PCT demonstrations of how people can control a single task, acting as an apparent single perceptual control system, are compelling. (Understanding to this level clarifies conflict resolution and personal interactions).

At the third level of explanation, Hierarchical PCT (HPCT) suggests an outline of a hierarchical arrangement of control systems as the organizing principle for the human nervous system. Demonstrations show the operation of such a hierarchy in humans, particularly at lower levels of perception and control. (Understanding to this level clarifies leadership issues).

At the fourth level of explanation, neurologists have identified control systems made up of a few neurons. See exhibit 25.

At the fifth level of explanation, researchers study the structure and interaction of neurons in terms of biology, chemistry and electronics.

PCT and HPCT offer no suggestions for mechanisms behind phenomena such as consciousness, awareness or attention. Understanding the operation of the human mind in greater detail will require research for many years to come, especially at the third through fifth levels of explanation outlined here, including biochemical control systems of several kinds.

It is not necessary to wait for additional research. Even a cursory understanding of the demonstrable concepts of PCT and HPCT offer immediate advantages, as this understanding leads to more effective and satisfying personal interactions.

Exhibit 21 and 22 continued with application to PCT:

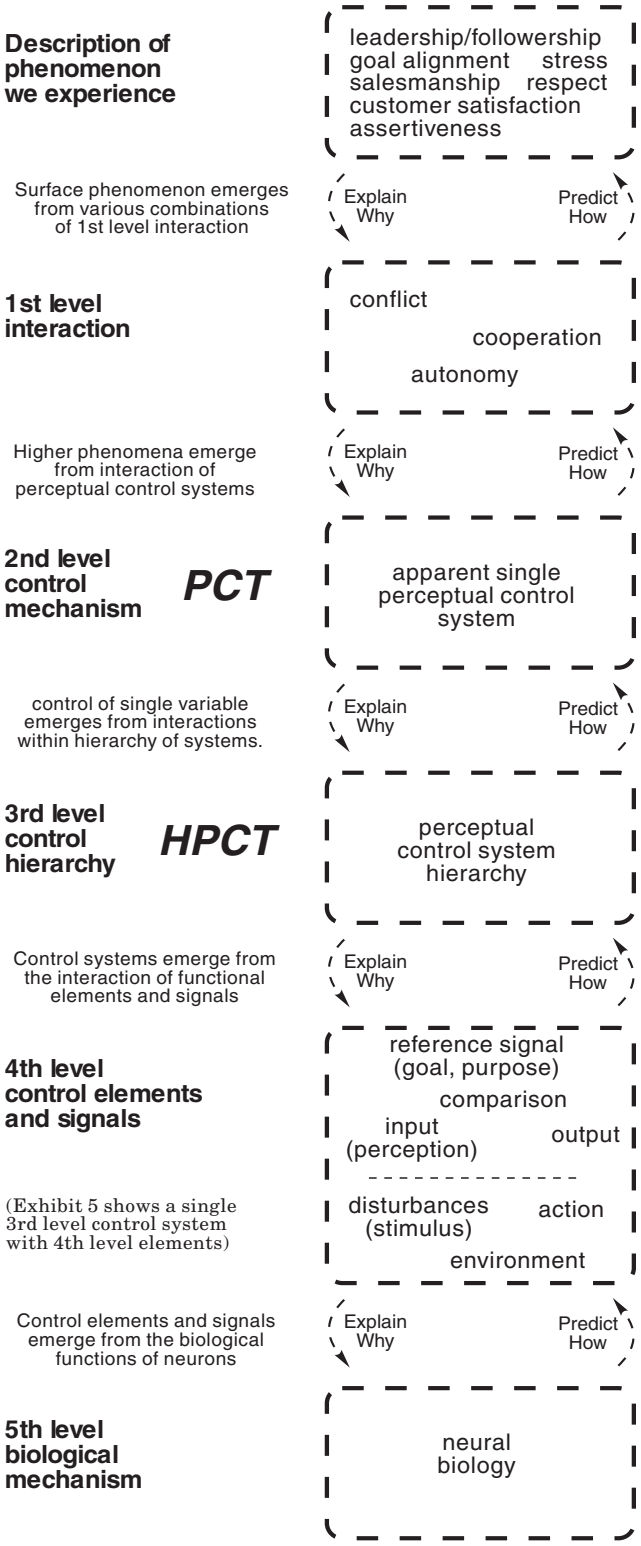

Exhibit 26. PCT psychology: Causal mechanisms in depth.

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Conclusion

The point of this discussion of theory and explanation is this: **All sciences of today are *not* created equal. The physical sciences we depend on today were not always dependable. The life sciences we cannot and should not depend on today may become dependable in the future.** The difference lies in the kind and depth of theory and explanation a science is based on. Descriptions in the life sciences are often uncertain to the point of uselessness compared to in-depth explanations based on causal mechanisms in the physical sciences. Progress can best be made when we discover, validate and apply in-depth casual explanations in the life sciences, just like we do in the physical sciences.

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